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Efficiency Enhancement of Solar PV Battery-Fed Electric Vehicles through Transformerless Buck-Boost Converter and Bidirectional DC-DC Control

Vishal Kumar[1], Pramod Kumar Rathore[2]

[1]M Tech Scholar, RKDF College of Engineering, Bhopal, Madhya Pradesh, India
[2]Assistant Professor, RKDF College of Engineering, Bhopal, Madhya Pradesh, India

ABSTRACT

In recent years, there has been a rise in automotive research on renewable energy-based battery charging systems for electric vehicles (EV). This study fully examines a solar PV battery-fed electric car using a transformerless buck-boost converter. Among the several advantages of employing batteries to store energy in ground vehicles are zero emissions, load levelling, and great transient performance. To achieve these requirements, a bidirectional DC-DC converter is required to connect the PV to the battery's dc-link. A PV-powered electric vehicle must be capable of charging and discharging in two separate modes. In this research, the Maximum Power Point Tracking (MPPT) approach is used to gather the most electricity from solar PV. Moreover, a DC-DC converter with bidirectional output necessitates the use of a closed-loop control circuit, which is suggested in this study. To boost efficiency, a novel solar MPPT system with an integrated transformerless Buck-Boost power converter was created. The article explains the Buck-boost power inverter's analysis, modelling, and control. To enhance PV energy extraction, the transformerless Buck-Boost power inverter incorporates a super boost converter and a buck converter through a variable mode controller. Lastly, research on the MPPT system with battery chargers and DC loads is carried out. Experiment findings reveal that output power rises clearly with increasing sun radiation. MATLAB simulations are performed to validate the system's effectiveness.

KEYWORDS: *Electric Vehicle; Solar; MPPT; P&O Algorithm; Transformerless Buck Boost Converter; Bidirectional DC/DC Converter; PI Controller*

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1. INTRODUCTION

Air pollution, particularly PM, is a serious challenge facing by transportation sector of various countries. The World Health Organization (WHO) reported 3.7 million death tragedies in the world below 60 in 2012 due to atmospheric air pollution, 90% population are located in developing countries [1]. Presently 1.7 million child expiries a year and total 9 million people died each year, says WHO [2,3]. And nearly18% of premature births (before 37 weeks gestation) (globally) are related to exposure to outdoor air pollution [3]. China reported 1.22 and 1.28 million premature death cases in 2005 and 2010, respectively [4]. According to an estimate of the 2017 Global Burden of Disease, atmospheric air pollution is responsible for more than 4.2 million early deaths, of these, India accounts for 1.1 million each year expiries [5]. Although due to smaller vehicle fleet relative to large population, India fixes low per capita transportation emissions. The big factor is the exponential growth of vehicle fleet, because of the growth in vehicle sales (about 10 million in 2007 to over 21 million in 2016 and expected to nearly double to about 200 million by 2030 in India [6]. A number of health and medical organizations claimed that the diesel engine exhaust is more prone to cancer in humans [7]. Also, rising fuel costs and growing public concerns on environmental problems such as air quality, global warming, etc. have led the governments and automobile industries to develop eco-friendly, emission-free means of transportation [8] i.e. green transportation systems e.g. walking, cycling, regular public conveyance, and rail transport system, etc. Vehicles include natural gas vehicle, hybrid energy vehicle, electric vehicle, hydro- gen-powered vehicle, and solar energy vehicle [9].

Vehicle emission standards are adopted to incorporate soot free fleet services around the world [10,11]. Countries like Europe, the United States, Japan, and India adopt Euro 6/VI equivalent standards (for light- and heavy-duty vehicles) that reduce 99% emissions like (NOx), (NH3), (N2O), etc. [12,6] and justifying the regulation of risk of ischemic heart disease, lung cancer, stroke, and asthma [13]. But the best option is renewable energy.

The outcome of this paradigm shift, EVs and PHEVs are emerging as attractive alternatives to ICEVs [14]. Owing to the importance of EVs, the national and international governments worldwide (U.S.A., U.K., China, Germany, France, Japan, Norway, Netherlands, etc.) have passed various resolutions and supervisory steps and allocated substantial fund to encourage EV and PEV deployment and implementation [15]. Long-term planning scenarios specify that the EVs must capture almost entire global vehicle fleet, mostly propelled by renewable sources, by 2050 to avoid worst-case global climate change scenarios [16].

The advantages of EV-PV charging system are.

1. Reduction in the EV charging load penetration on the grid.
2. The voltage problem in the distribution system is avoided [17].
3. Electric supply charges paid to the utility are also reduced.
4. Efficiency is on the higher side in direct DC EV-PV interconnection.
5. Energy storage reduces as EV battery doubles up the PV storage.
6. Feasibility of Vehicle-to-grid (V2G) and Vehicle-to-home (V2H) strategies [18–22].
7. Lower fuel cost and no emissions at the tailpipe (‘well to wheel’) [23].
8. No maintenance/noise because of no moving part.
9. Installation is feasible everywhere [24].

2. PHOTOVOLTAIC MODELLING

In general, photovoltaic (PV) arrays convert sunlight into electricity. DC power generated depends on illumination of solar and environmental temperature which are variable. It is also varied according to the amount of load. Under uniform irradiance and temperature, a PV array exhibits a current-voltage characteristic with a unique point, called maximum power point, where the PV array produces maximum output power. In order to provide the maximum power for load, the maximum-power-point-tracking (MPPT) algorithm is necessary for PV array. Briefly, an MPPT algorithm controls converters to continuously detect the instantaneous maximum power of the PV array [2].

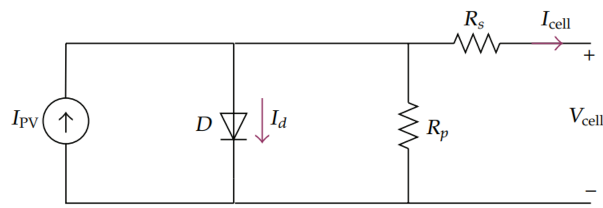

Fig. 1: Equivalent circuit of PV model.

A. Ideal PV Cell Model

The equivalent circuit of the ideal PV cell is shown in Fig. 1. The basic equation from the theory of semiconductors [3] that mathematically describes the I-V characteristic of the ideal PV cell is as follows:

$$I = I_{PV,cell} \quad I_{0,cell} \left[\exp\left(\frac{qV}{akT}\right) \quad 1\right] \qquad (1)$$

$$I_d = I_{0,cell} \left[\exp\left(\frac{qV}{akT}\right) - 1\right] \qquad (2)$$

where $I_{PV,cell}$ is the current generated by the incident light (it is directly proportional to the sun irradiation), I_d is the Shockley diode equation, $I_{0,cell}$ is the reverse saturation or leakage current of the diode, q is the electron charge ($1.60217646 \times 10^{-19}$ C), k is the Boltzmann constant ($1.3806503 \times 10^{-23}$ J/K), T (in Kelvin) is the temperature of the p-n junction, and “a” is the diode ideality constant [4].

A. Modeling the PV Array

Equations (1) and (2) of the PV cell do not represent the *V-I* characteristic of a practical PV array. Practical arrays are composed of several connected PV cells and the observation of the characteristics at the terminals of the PV array requires the inclusion of additional parameters to the basic equation [3, 4]:

$$I = I_{PV} - I_0 \left[\exp\left(\frac{V + R_s I}{V_t a}\right) - 1\right] - \frac{V + R_s I}{R_p} \qquad (3)$$

where I_{PV} and I_0 are the PV current and saturation currents, respectively, of the array and $V_t = N_s kT/q$ is the thermal voltage of the array with N_s cells connected in series. Cells connected in parallel increase the current and cells connected in series provide greater output voltages. If the array is composed of N_p parallel connections of cells, the PV and saturation currents may be expressed as $I_{PV} =$

$N_p\, I_{PV,cell}$, $I_0 = N_p\, I_{0,cell}$. In (3), R_s is the equivalent series resistance of the array and R_p is the equivalent parallel resistance. Equation (3) describes the single-diode model presented in Fig. 1 [4].

All PV array datasheets bring basically the following information: the nominal open- circuit voltage ($V_{oc,n}$), the nominal short-circuit current ($I_{sc,n}$), the voltage at the MPP (V_{mpp}), the current at the MPP (I_{mpp}), the open-circuit voltage/temperature coefficient (K_V), the short-circuit current/temperature coefficient (K_I), and the maximum experimental peak output power (P_{max}). This information is always provided with reference to the nominal condition or standard test conditions (STCs) of temperature and solar irradiation. Some manufacturers provide *I-V* curves for several irradiation and temperature conditions. These curves make easier the adjustment and the validation of the desired mathematical *I-V* equation. Basically, this is all the information one can get from datasheet of PV arrays [4].

Electric generators are generally classified as current or voltage sources. The practical PV device presents hybrid behavior, which may be of current or voltage source depending on the operating point. The practical PV device has a series resistance R_s whose influence is stronger when the device operates in the voltage source region and a parallel resistance R_p with stronger influence in the current source region of operation. The R_s resistance is the sum of several structural resistances of the device. R_s basically depends on the contact resistance of the metal base with the p semiconductor layer, the resistances of the p and n bodies, the contact resistance of the n layer with the top metal grid, and the resistance of the grid [5]. The R_p resistance exists mainly due to the leakage current of the p-n junction and depends on the fabrication method of the PV cell. The value of R_p is generally high and some authors neglect this resistance to simplify the model. The value of R_s is very low, and sometimes this parameter is neglected too.

The *V-I* characteristic of the PV array, shown in Fig. 2, depends on the internal characteristics of the device (R_s, R_p) and on external influences such as irradiation level and temperature.

The amount of incident light directly affects the generation of charge carriers and, consequently, the current generated by the device. The light-generated current (I_{PV}) of the

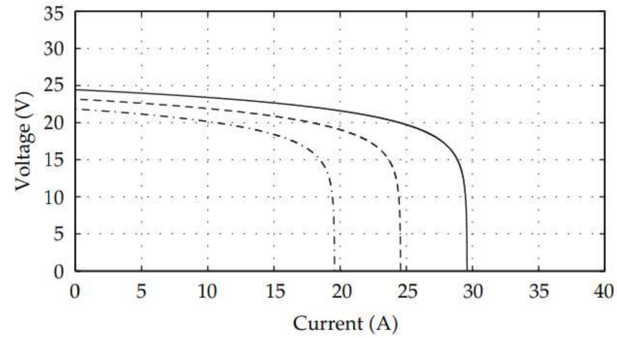

Fig. 2: V-I characteristic of PV.

elementary cells, without the influence of the series and parallel resistances, is difficult to determine. Datasheets only inform the nominal short-circuit current ($I_{sc,n}$), which is the maximum current available at the terminals of the practical device. The assumption $I_{sc} \approx I_{PV}$ is generally used in the modeling of PV devices because in practical devices the series resistance is low and the parallel resistance is high. The light-generated current of the PV cell depends linearly on the solar irradiation and is also influenced by the temperature according to the following equation (4), [2, 4, 6–8]

$$I_{PV} - \left(I_{PV,n} + K_I \Delta T\right) \frac{G}{G_n} \qquad (4)$$

where $I_{PV,n}$ (in amperes) is the light-generated current at the nominal condition (usually 25°C and 1000 W/m^2), $\Delta T = T - T_n$ (T and T_n being the actual and nominal temperatures (in Kelvin), resp.), G (watt per square meter) is the irradiation on the device surface, and G_n is the nominal irradiation. $V_{t,n}$ is the thermal voltage of N_s series-connected cells at the nominal temperature T_n.

The saturation current I_0 of the PV cells that compose the device depend on the saturation current density of the semiconductor (J_0, generally given in [A/cm^2]) and on the effective area of the cells. The current density J_0 depends on the intrinsic characteristics of the PV cell, which depend on several physical parameters such as the coefficient of diffusion of electrons in the semiconductor, the lifetime of minority carriers, and the intrinsic carrier density [9]. In this paper the diode saturation current I_0 is approximated by the fixed value (6 mA).

The value of the diode constant "*a*" may be arbitrarily chosen. Many authors discuss ways to estimate the correct value of this constant. Usually, $1 \leq a \leq 1.5$ and the choice depends on other parameters of the *I-V* model. Some values for "*a*" are found in [6] based on empirical analyses. Because "*a*" expresses the degree of ideality of the diode and it is totally empirical, any initial value of "*a*" can be chosen in order to adjust the model. The value of "*a*" can be later modified in order to improve the model fitting, if necessary. This constant affects the curvature of the V-I curve and varying a can slightly improves the model accuracy [4].

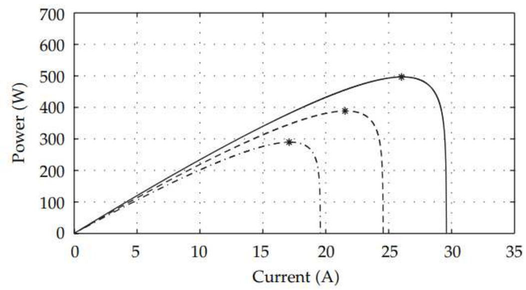

Fig. 3: P-I characteristic of PV.

2.1. STAND -ALONE SOLAR POWER SYSTEM

The solar PV system consists of a PV module, the dc/dc boost converter, the maximum power point tracking algorithm and the load. Radiation (R) is incident on the PV module. It generates a voltage (V) and current (I) which will be fed into the load [3]. The voltage power characteristic of a photovoltaic (PV) array is nonlinear and time varying because of the changes caused by the atmospheric conditions. When the solar radiation and temperature varies the output power of the PV module also changes. In order to obtain the maximum efficiency of the PV module, it must operate at the maximum point of the PV characteristic. The most extreme power point relies upon the temperature and irradiance which are non-direct in nature. The greatest power point following control framework is utilized and work viability on the non-straight varieties in the parameters, such as temperature and radiations [4]. A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load. A dc/dc converter (boost converter) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the load and the module. The dc/dc converter with maximum power point tracking algorithm and the load is shown in Fig. 4. By changing the duty cycle, the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power. Therefore, MPPT techniques are needed to maintain the PV array's operating at its MPP [3].

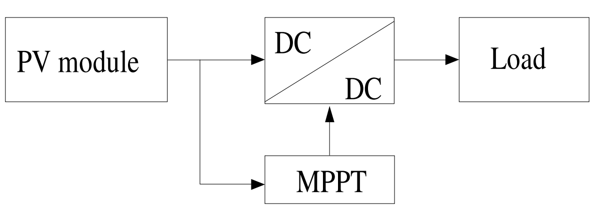

Fig. 4: Block Diagram of PV System with MPPT

2.2. MAXIMUM POWER POINT TRACKING

Most extreme Power Point Tracking (MPPT) is helpful apparatus in PV application. Sun oriented radiation and temperature are the primary factor for which the electric power provided by a photovoltaic framework. The voltage at which PV module can create greatest power is called 'most extreme power point (pinnacle control voltage). The primary rule of MPPT is in charge of separating the greatest conceivable power from the photovoltaic and feed it to the heap by means of dc-to-dc converter which steps up/ down the voltage to required size [5]. The operating point of a PV generator is located at the intersection of its current-voltage curve with the load-line. This operating point may be far from the maximum power point (MPP) of the generator wasting a significant part of the available solar power. To achieve optimum matching between the PV generator and the load, an MPP tracker, normally comprised of a simple dc-dc converter, is used. The duty ratio of the converter is controlled by an MPPT algorithm to maximize the power delivered to the load.

A number of different MPPT algorithms have been proposed [1-3], including the P&O algorithm. This simple algorithm does not require previous knowledge of the PV generator characteristics or the measurement of solar intensity and cell temperature and is easy to implement. The algorithm perturbs the operating point by increasing or decreasing a control parameter by a small amount and measures the PV array output power before and after the perturbation. If the power increases, the algorithm continues to perturb the system in the same direction; otherwise the system is perturbed in the opposite direction (Fig. 5).

There are two common approaches for implementing the P&O algorithm; reference voltage perturbation [4-10] and direct duty ratio perturbation [5, 7, 11-13]. For reference voltage perturbation, the PV array output voltage reference is used as the control parameter in conjunction with a controller (usually a PI controller) to adjust the duty ratio of the MPPT power converter. The PI controller gains are tuned while operating the system at a constant voltage equal to the standard test condition (STC) value of the MPP voltage. These gains are kept constant while the reference voltage is controlled by the MPPT algorithm. For direct duty ratio perturbation, the duty ratio of the MPPT converter is used directly as the control parameter.

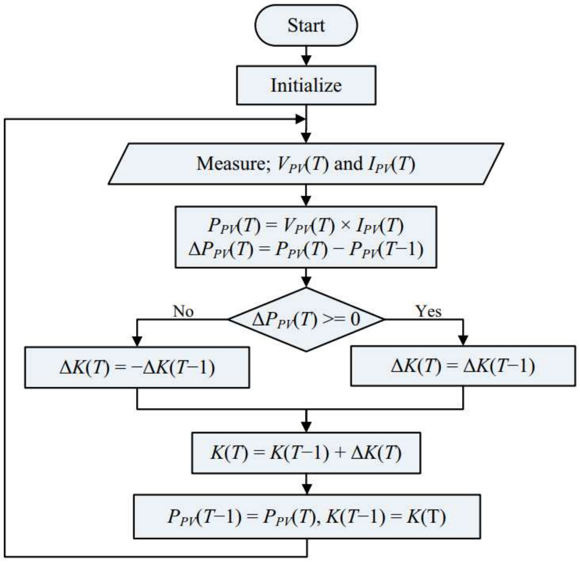

Fig. 5: Flowchart of P&O MPPT algorithm

3. TRANSFORMERLESS BUCK-BOOST CONVERTER

Identifying, evaluating and analysing the growing environmental issues addresses us to use more efficient, clean source of energy.

Taking fuel cells into account, it is an effective alternative clean energy source and has less hazardous effects on the environment. Due to its high efficiency, steady operation with a renewable source of energy it can be used as power supplies that have better backup facilities and many other brilliant features. The fuel cell output voltage is variable and due to its low output, directly it cannot be connected to load. To overcome difficulties and to make it more beneficial, the buck-boost dc-dc converter is essential for the applications which required constant DC voltage.

The conventional buck-boost converter efficiency is low and due to its limited effects, it is not proper for fuel cells sources [1]. A several boost dc-dc converters have been introduced to get high-level voltage gain and high efficiency and a novel control technique can be introduced to operate with low duty cycle [2]. A flyback converter with low duty cycle can achieve high-level voltage gain. It can be done so by raising the turn's ratio of the transformer but its converter efficiency is low due to leakage inductor and reverses recovery problems. The power switches suffer voltage spike through it [3, 4]. High amount of voltage gain dc-dc converters with a coupled inductor is another option. Here, the leakage inductance of this coupled capacitor adds voltage stress and cause high voltage spike [5, 6].

A high conversion ratio bi-directional dc-dc converter consists of five switches. It decreases the efficiency and increases the circuit cost and conduction losses [7]. Two power switches are utilized in a transformerless interleaved high buck converter, and it charges converter capacitor. Voltage Gain for transformerless buck-boost dc-dc converters are doubles that of traditional buck-boost converter. The paper here presents a transformerless buck- boost dc-dc converter with low voltage stress on the switch and high boost voltage gain is designed and it utilizes only single switch [8]. The designed converter voltage gain is higher than other converters like buck-boost, boost, ZETA, SEPIC and CUK converters. The designed converter consists of single switch. The output voltage is greater than the voltage stress across diode and switch, so the efficiency of designed converter can be enhanced and conduction loss of power switch can be reduced. The designed converter functions as a power supply and its input current is discontinues, hence it is convenient for low power and low voltage applications. The converter here can be widely used, it can be used in gadgets like mobiles and LED drives, electric vehicles and systems with fuel cell. Simulations results are provided so as to verify the feasibility of the converter. The simulation is done in matrix laboratory (MATLAB) Simulink software, and the results are verified.

3.1. SYSTEM DESIGN

A. DC-DC CONVERTER

There are several techniques such as linear, electronics, capacitive, switched mode; magnetic, capacitive is used to vary DC electrical power at different voltage levels. They are used to increase or decrease according to its need and applications. It takes the power from the battery and steps down the voltage level, similarly, according to need the voltage level is reduces. It has two types that are Isolated and Non- Isolated depending on its applications. Isolated DC-DC converter requires more than four switches in which breaking of the ground loop is done. While Non-Isolated consists of inductors and two switches which provide high efficiency. To run a radio, it might be necessary to step down the power of the large battery of 24 V to 12 V.

B. BUCK-BOOST CONVERTER

Buck-Boost converter works to either boosting or bucking the voltage, the output voltage can be increased or decreased. It is commonly used to reverse the polarity. The output voltage varies from 0 to Vi and Vi to ∞.

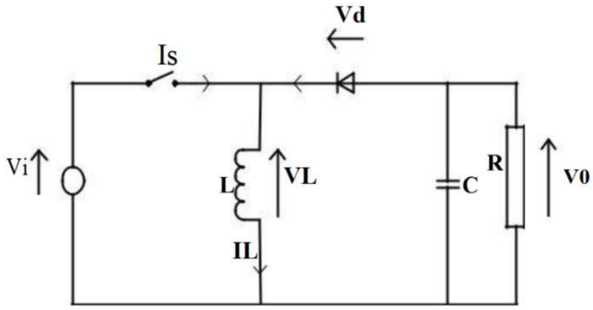

Fig. 6: Basic Circuit of Buck-Boost Converter

The main principle of Buck-boost converter is described below:

1. ON STATE: Inductor L, starts accumulating energy since an inductor L is connected by input voltage. The capacitor makes sure that the steady state is a constant output voltage and provides the energy to the load.

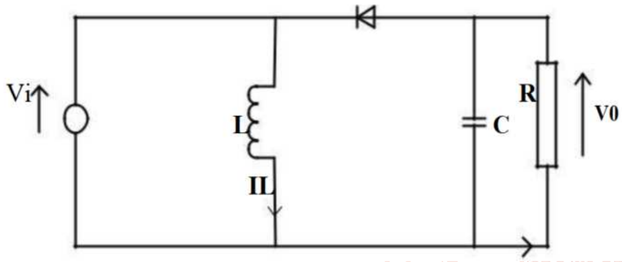

Fig. 7: ON State of Buck-Boost Converter

2. OFF STATE: Here, the output load and the capacitor are connected to an inductor. This provides output voltage/load higher or lower than the source voltage.

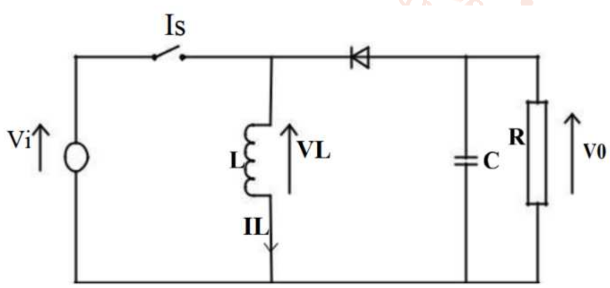

Fig. 8: OFF State of Buck-Boost Converter

3.2. CONFIGURATION OF BIDIRECTIONAL CONVERTER

Bidirectional converters are employed to transfer the power among two DC sources in both directions. These converters are comprehensively used in diverse utilizations. It acts as a mandatory one for assembling the energy storage systems with PV. These converters serve the purpose of stepping up or stepping down and also same the voltage level transfer between its input and output along with the capability of power flow in both the directions. The Bidirectional DC-DC converter is widely used in various applications such as fuel storage areas, hybrid vehicles and uninterruptable power supplies. These systems are always backed up and supported by the sources which are rechargeable such as battery units. The bidirectional DC-DC converter is required to permit power flow in both the directions at the standardized level. In case of low DC bus voltage the bidirectional converter is used to transfer the solar energy power to the load. The circuit diagram of the proposed work is shown in the fig. 9.

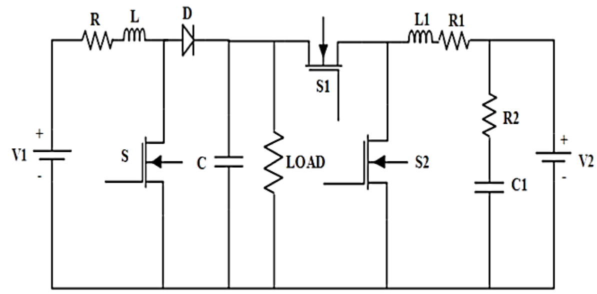

Fig. 9: Proposed circuit diagram

The first half of the circuit is the DC-DC boost converter design and the second half is the bidirectional DC-DC converter. The boost converter design is provided for the solar system. Any type of converters either Boost, Buck or Buck-boost is used to match the intrinsic impedance level of PV panels with the impedance of load. Hence maximum power transfer is possible. MPPT is obtained by manipulating the duty cycle ratio of DC-DC converter, hence PV panel operates at its maximum power point.

In our proposed work, we used boost converter which connects PV array with load. MPPT algorithm modifies the duty ratio such that PV array is operated at voltage corresponding to maximum power point. Generally, in areas other than Solar PV, input to boost converter is constant voltage source. In those circuits duty ratio is measured based on the required amplification and circuit parameters are found based on allowable range of ripple. But, in case of photovoltaic applications the input is PV array which is a non-linear dependent current source.

First, we should design the boost converter considering required output voltage for load. The functioning of boost converter is checked based on the constant power level by changing the load. By altering the load voltage and current changes accordingly but output power and input power for boost converter must be same. If any difference occurs, it indicates the losses. The next stage is bidirectional DC-DC converter which operates in forward and reverse directions. It is described below in detailed manner.

A. Bidirectional converter circuit

The bidirectional DC-DC converter is one of renowned types of DC-DC converter. It performs both buck and boost operations and it has the ability to reverse the current flow direction and also the power transfer between two DC sources. It acts as buck mode when it charges the battery and it acts as boost mode when the battery discharges power to load. This topology incorporates a non-isolated bidirectional converter for a battery charging and discharging areas. The bidirectional power flow for battery charging and discharging is carried out by using two switches. Here, MOSFET is used as switch.

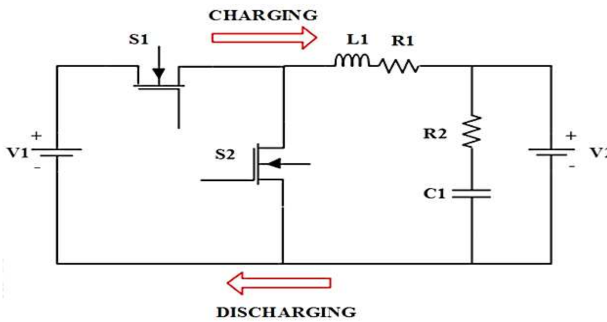

Fig. 10: Bidirectional converter circuit

In the proposed circuit given above, there are two DC sources which are represented as V1 and V2. Where V1 is the solar PV panel and V2 is the battery. Since, the PV system output power is mainly depended on weather conditions, sometime PV produces more power than the load requirement and hence the excess power will be stored in the Battery using bidirectional switches, which can be later used during night time and in case of seasonal modifications in weather. These converters are habitually used in variety of applications, like hybrid power networks, and battery storage systems.

The bidirectional conversion is carried out by two switches, and are regulated with the help of controllers. During boost mode the switch S1 is ON and switch S2 is OFF. At buck mode the switch S2 is ON and switch S1 is OFF. Cross conduction issues will not persists, since the switching operations are carried out based on the provided dead time appropriately. Due to the availability of compensation source, the output will be provided continuously to the DC load based on the requirement without any interruption. The main aim of this proposed system is to provide uninterruptable supply with the help of bidirectional topology. The merits of this propose work are it requires less components, it does not require transformer, low cost, and provides high efficiency.

There are two different operating modes. They are buck mode and boost mode.

Mode- 1

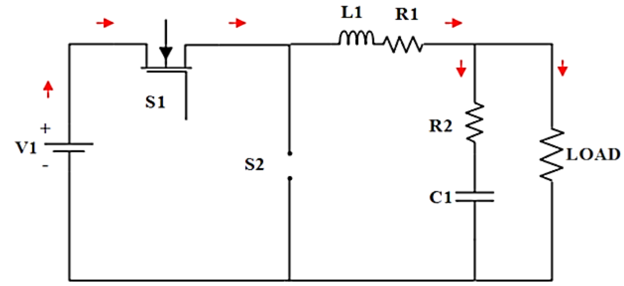

Fig. 11: Mode 1

The function of Mode 1 is represented in the fig. 11. The buck mode is the first operating mode and is also called as forward power flow mode. This mode comes into act, when the generated solar power is greater than the load requirement and when the battery does not have full charge. At this mode switch S1 will be turned on and switch S2 will be turned off. Through S1 the power from the solar panel will be supplied to the battery for charging purpose. When switch S1 is ON, the input current rises and flows through S1 and L. When S1 is OFF, the inductor current falls until the next cycle. The energy stored in inductor L is supplied for charging the battery. At this mode the PV panels supplies power to the load and as well as charge the battery through the excess power generated by PV. At this mode the battery is charged through buck mode.

Mode- 2

The function of Mode 2 is represented in the fig. 12. The boost mode is the second operating mode and is also called as reverse power flow mode. This mode comes into act, when the generated solar power is lesser than the load requirement, but the battery will have full charge, hence it will provide compensation and supply the power to load. At this mode switch S2 will be turned on and switch S1 will be turned off

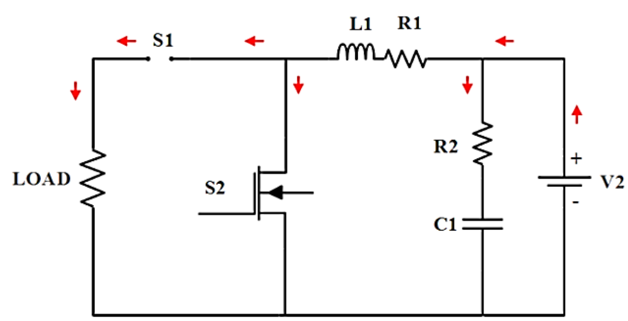

Fig. 12: Mode 2

Through S2, the power from the battery will be supplied to the load by discharging the battery. When switch S2 is ON, the input current rises through inductor L and S2.When S2 is OFF, the inductor current falls until the next cycle. The energy stored in inductor L flows through the load. At this mode the battery provides compensation until it discharges fully. The PV panels also supplies the power to load with the help of boost converter associated with it. Hence, in this mode the battery provides power to load through boost mode.

4. PV Array-Battery powered EV-PMDC Drive Scheme

DC Motors have lots of desirable properties. Some of them are reliability, durable, inexpensive, and also using in low voltages, having positive conversion coefficients between electrical and mechanical, having size and design variation. For these reasons, the DC motors are utilized in many applications.

A permanent magnet dc motor (PMDC) is one of the DC motor types. PMDC system converts electrical power provided by a voltage source to mechanical power provided by a spinning rotor by means of magnetic coupling. The equivalent circuit of a PMDC motor is illustrated in Fig. 13. The armature coil of the dc motor can be presented by an inductance (L_m) in series with resistance (R_a) in series with an induced voltage (e_m) which opposes the voltage source.

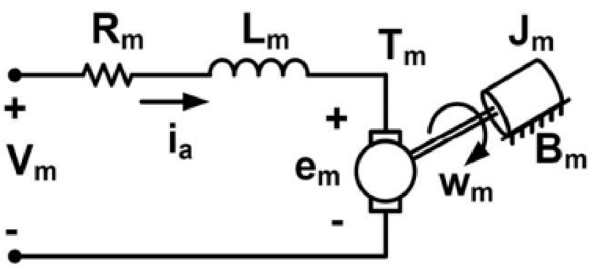

Fig. 13: The equivalent circuit of a dc motor

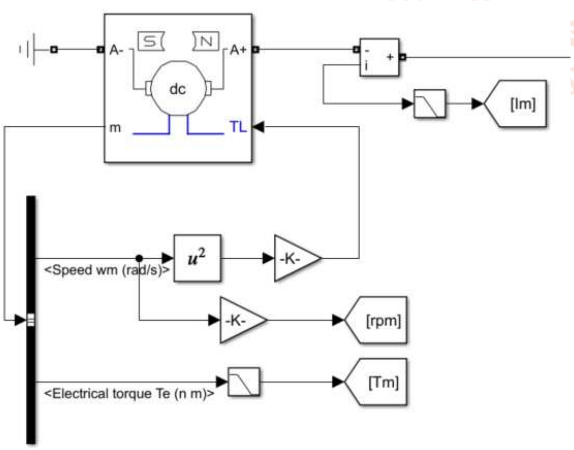

Fig. 14: The MATLAB/Simulink functional model of the PMDC motor

4.1. Simulation Results and Analysis

The complete EV model is simulated in MATLAB, the detailed simulation results along with discussions as follows.

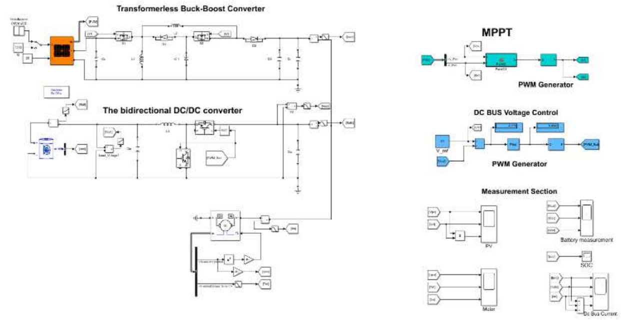

Fig. 15: Solar PV Battery Fed Electric Vehicle with Transformer less Buck Boost Converter

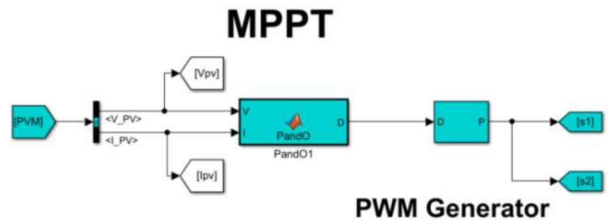

Fig. 16: MPPT Algorithm (P&O)

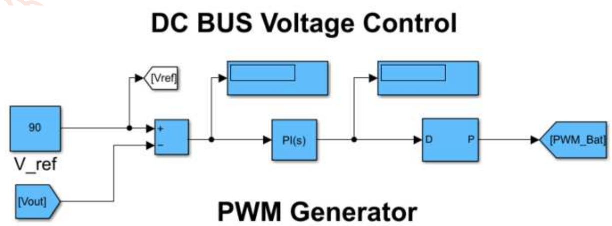

Fig. 17: DC Bus Voltage Control (PWM Generator)

To analyze the performance of the solar PV battery fed electric vehicle with transformer less buck boost converter. The PV parameters of the system are shown in Table I.

TABLE I: PV PARAMETERS

Parameters	Specifications
Maximum power (W)	305.0063 W
Parallel strings	3
Series-connected modules per string	2
Cells per module (Ncell)	72
Open circuit voltage Voc (V)	44.88
Short-circuit current Isc (A)	8.95
Voltage at maximum power point Vmp (V)	35.59
Current at maximum power point Imp (A)	8.57

At different irradiances (1000, 500, and 1000 IR) and temperatures of 25 degrees Celsius, the performance of a solar PV battery-fed electric vehicle with a transformer-less buck boost converter was evaluated. In solar mode, 1000 IR and 25 °C are utilized for 0-5 seconds of solar-powered electric vehicle operating, and the battery is charged with solar energy. In battery mode, 500 IR and 25 °C work in 5 to 10 seconds. Electric vehicle run entirely on battery power. Solar Mode was then cycled through for 10 to 15 seconds. SOC of battery is keep Increasing, motor speed, torque and current maintained.

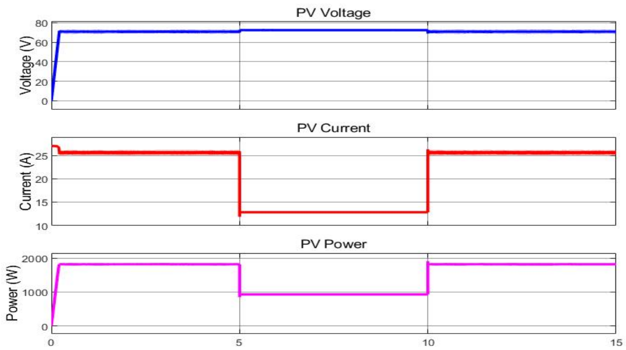

Fig. 18: PV Voltage, PV Current & PV Power Vs Time in (S)

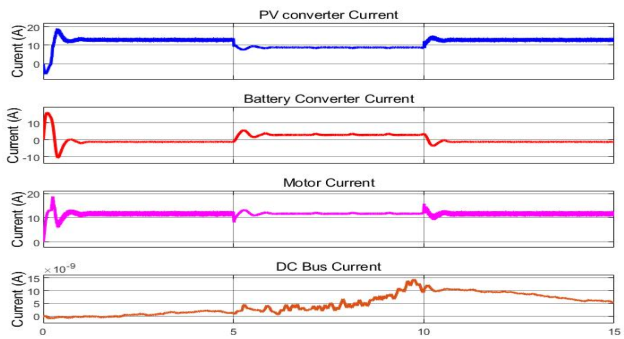

Fig. 19: PV Converter Current, Battery Converter Current, Motor Current & Dc Bus Current Vs Time in (S)

4 * 12V batteries with 48 Ah each are connected to a bidirectional DC/DC converter that is controlled by a DC bus voltage control system.

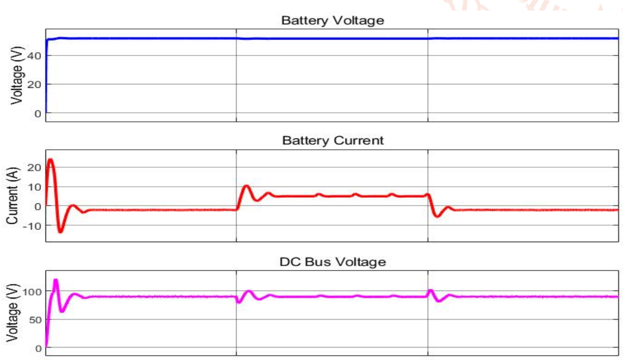

Fig. 20: Battery Voltage, Battery Current & Dc Bus Voltage Vs Time in (S)

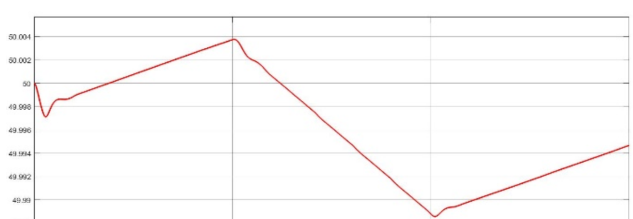

Fig. 21: State of charge - SOC % Vs Time in (S)

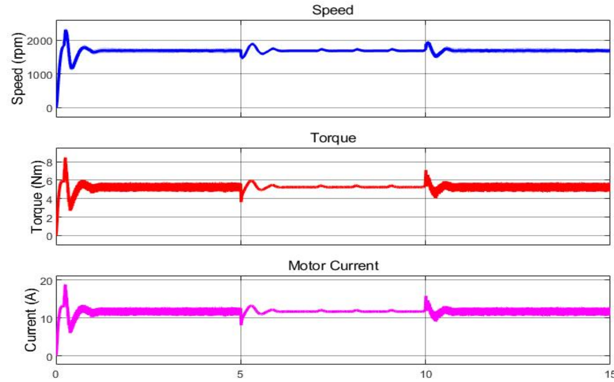

Fig. 22: Motor Speed, Motor Torque & Motor Current Vs Time in (S)

5. CONCLUSION

In this study, we describe and test a solar PV battery-fed electric vehicle using a transformerless buck-boost converter for optimum power point tracking. A transformerless buck-boost converter may operate in both buck and boost modes, depending on the output needs. Typically, a buck-boost converter is used between the solar panel and the load side's DC bus. The MPPT algorithm controls the transformerless buck boost converter (P&O). We provide the PV voltage and current to P&O MPPT, which generates the duty cycle. The pulse will be generated when the PWM generator has processed the duty cycle. When that pulse is applied to the Buck boost converter, it will extract the maximum power from the PV panel. The PMDC motor will operate as an electric vehicle, taking power from both solar and battery sources depending on irradiance and temperature. A bidirectional DC/DC converter operated by a DC bus voltage control system is attached to the battery. Since the PMDC motor rating is 90V, we must maintain the DC bus voltage at 90V in order to run the EV system. This process will be carried out through the PI controller, which will produce the duty cycle for the PWM generator, after which the PWM generator will generate the pulses for the bidirectional converter to regulate the current flow in the system as well as to maintain the voltage across the DC bus. The experimental findings suggest that the topology could successfully increase the energy transfer efficiency of MPPT technology, which meets the future development of EV systems.

References

[1] Jelena Stojkovic "Multi-Objective Optimal Charging Control of Electric Vehicles in PV charging station" 2019 16th International Conference on the European Energy Market (EEM).

[2] T. S. Biya; M. R. Sindhu "Design and Power Management of Solar Powered Electric Vehicle Charging Station with Energy Storage System"

2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA).

[3] Jing Zhang; Ruiming Yuan "A Non-Cooperative Game Based Charging Power Dispatch in Electric Vehicle Charging Station and Charging Effect Analysis" 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2).

[4] Taoyong Li; Jing Zhang "An Optimal Design and Analysis of a Hybrid Power Charging Station for Electric Vehicles Considering Uncertainties" IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics.

[5] Juan Liu "Research on electric vehicle fast charging station billing and settlement system" 2017 2nd IEEE International Conference on Intelligent Transportation Engineering (ICITE).

[6] Sanchari Deb; Karuna Kalita; "Impact of electric vehicle charging stations on reliability of distribution network" 2017 International Conference on Technological Advancements in Power and Energy (TAP Energy).

[7] Hongliang Liu; Biao Zhang "The output planning model of the electric vehicle charging stations based on game theory" 2016 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC).

[8] Mojgan Bashiri; Nastaran Bahadori "Optimized plan of charging stations for management of demands: An emerging need of hybrid electric vehicle" 2016 Future Technologies Conference (FTC).

[9] Haoming Liu; Man Niu; Weijie Wang "Reserving charging strategy for electric vehicles based on combined model of road-charging station-electric vehicle" 2016 IEEE 2nd Annual Southern Power Electronics Conference (SPEC).

[10] Xiaoxue Rong; Bo Wang; Chuanjun Shao "Coordinated charging strategy of electric vehicle charging station based on combination of linear power flow and genetic algorithm" 2016 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC).

[11] Oliver Marcincin; Zdenek Medvec" Active charging stations for electric cars "2015 16th International Scientific Conference on Electric Power Engineering (EPE).

[12] Taha N. Gucın; Kayhan Ince; Filiz Karaosmanoğlu" Design and power management of a grid-connected Dc charging station for electric vehicles using solar and wind power 2015 3rd International Istanbul Smart Grid Congress and Fair (ICSG).

[13] Ilhami Colak; Ramazan Bayindir; Ahmet Aksoz" Designing a competitive electric vehicle charging station with solar PV and storage" 2015 IEEE International Telecommunications Energy Conference (INTELEC).

[14] Ryszard Pawełek; Pawel Kelm; Irena Wasiak" Experimental analysis of DC electric vehicles charging station operation and its impact on the supplying grid" 2014 IEEE International Electric Vehicle Conference (IEVC).

[15] Huajie Ding; Zechun Hu; Yonghua Song" Coordinated control strategy of energy storage system with electric vehicle charging station" 2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific).

[16] Oliver Marcincin; Zdenek Medvec" Concept of charging stations for electric cars" Proceedings of the 2014 15th International Scientific Conference on Electric Power Engineering (EPE).

[17] Qin Yan; Ilaval Manickam; Mladen Kezunovic; Le Xie" A multi-tiered real-time pricing algorithm for electric vehicle charging stations" 2014 IEEE Transportation Electrification Conference and Expo (ITEC).

[18] Wu Guoliang; Xu Bingliang; Yu Haiyang; Dong Erjia" Power quality analysis and harmonic suppression of high latitude and high alpine region electric vehicles charging station" 2013 World Electric Vehicle Symposium and Exhibition (EVS27).

[19] Bram Rotthier; Thomas Van Maerhem; Pascal Blockx; Peter Van den Bossche; Jan Cappelle" Home charging of electric vehicles in Belgium" 2013 World Electric Vehicle Symposium and Exhibition (EVS27).

[20] Hans Håvard Kvisle; Bjarne André Myklebust" Development of charging station data services for new user groups" 2013 World Electric Vehicle Symposium and Exhibition (EVS27).

[21] Wang Meng; Liu Kai; Zhao Songhui" Evaluation of Electric Vehicle Charging Station Sitting Based on Fuzzy Analytic Hierarchy Process" 2013 Fourth International Conference on Digital Manufacturing & Automation.

[22] Xiaolei Li; Haixing Li; Jingchao Zhang; Yuexin Liu; Yuanli Niu;Ningxi Song" Dynamic breakeven analysis on the charging price of electric vehicle charging station" 2012 China International Conference on Electricity Distribution.

[23] Wenhai Yang; Jingmin Wang; Zhanlong Zhang; Yajing Gao" Simulation of electric vehicle charging station and harmonic treatment" 2012 International Conference on Systems and Informatics (ICSAI2012).

[24] Dawei Zhao; Lingzhi Zhu; Wei Wang; Ning Chen; Hao Zhang; Feng Ni" Calculation of harmonic suppression and reactive power compensation device's capacity configuration in electric vehicle charging Stations" 2012 China International Conference on Electricity Distribution.

[25] Yu Liu; Buxiang Zhou; Chao Feng; Shouwen Pu" Application of Comprehensive Evaluation Method Integrated by Delphi and GAHP in Optimal Siting of Electric Vehicle Charging Station" 2012 International Conference on Control Engineering and Communication Technology.

[26] Shaoyun Ge; Liang Feng; Hong Liu" The planning of electric vehicle charging station based on Grid partition method" 2011 International Conference on Electrical and Control Engineering.

[27] Wang Meng; Liu Kai" Optimization of electric vehicle charging station location based on game theory" Proceedings 2011 International Conference on Transportation, Mechanical, and Electrical Engineering (TMEE).

[28] Liu Yongxiang; Xu Ruilin; Chen Tao; Zhang Xiaoyong; Wang" Investigation on the construction mode of the charging station and battery-swap station" 2011 International Conference on Electric Information and Control Engineering.

[29] Mehdi Etezadi-Amoli; Kent Choma; Jason Stefani" Rapid-Charge Electric-Vehicle Stations" Year: 2010 | Volume: 25, Issue: 3 | Journal Article | Publisher: IEEE.

[30] Xiaoxing Zhu; Houtao Chen; Wulin Liu; Jie Luo" Design and exploitation of supervisory control system for commercial electric vehicle charging station based on virtual DPU technology" 2010 International Conference on Power System Technology.